MFP Geoacoustic Inversion of Haro Strait Array Data

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LONG TERM GOALS

The primary long term objective of this project is:

- to provide a rapid, real-time, efficient, wide area assessment technique to estimate full 3-D (range, depth, and azimuth) geoacoustic shallow water parameters. These parameters include *geometric* values such as source location, array element location (arrays can be non-linear), and water depths as well as *bottom properties* such as sediment layer thicknesses, sound-speeds, densities, and attenuations).

This wide area assessment would be made via multiple rapidly deployed receiver arrays and multiple broadband low frequency sources. The environmental parameters could then be used as inputs to signal processing methods for the detection, localization, and identification of targets or for monitoring of the region for effects such as global warming or for the tracking of marine mammals.

OBJECTIVES

The objectives of this work include

- continued evaluation of parameter sensitivities for inversion optimization;
- continued investigation of geoacoustic inversion for range-dependent slices;
- investigation of the *geometric* parameters critical to geoacoustic inversions. These properties are primarily the source location (range and depth) as well as the receiver array element locations (array can be non-linear) and the water depths along the source-to-receiver path;
- incorporation of the RAMGEO PE model into the SUB-RIGS model.

APPROACH

The Matched Field Processing (MFP) tomographic inversion for *geoacoustic parameters* is a relatively new inversion approach which can combine the SUB-RIGS method (Tolstoy, '98; '03, '04a,b) or any single slice inversion data with the linearized tomographic MFP method LINTOMO (Tolstoy et al., '91; Tolstoy, '92, '94). It is designed specifically for rapid, high resolution 3-D estimation of shallow water environmental parameters. The LINTOMO *plus* SUB-RIGS approach entails the analysis of low frequency components (from 50 to 500Hz in shallow water) for multiple sources densely deployed around and through an ocean region and heard on widely distributed *arrays* of receivers. For shallow water the vertical arrays

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should ideally span the water column although this is not necessary and is not available for the Haro Strait data.

Prior to input to LINTOMO the individual path data m Prior to input to LINTOMO the individual path data must be "inverted". Thus, in preparation some data have been examined in terms of their *geometric* properties in order to infer source and array parameters such as source depth, array phone depths and ranges, as well as the average flat water depth for the path. This approach uses simple ray paths to estimate arrival time differences based on geometry alone as compared with the data. The geometric relationships at issue are shown in Fig. 1. The approach *extends* that of Michalopoulou and Ma, '05, by examining non-uniqueness of the time domain difference optimization in more detail and in simulating the resultant time domain fields for comparison with the Haro Strait data.

WORK COMPLETED

Recent work (FY05) has resulted in:

- Preliminary broadband analysis of the nw014 path of Haro St data. Results at several FFT frequencies both for test and simulated data were presented at the Vancouver ASA meeting (5/05).
- Time domain analysis of several paths of Haro St data (nw014, nw024, sw029) to find the possible geometries of the paths. Generation of pulse signals for the optimized geometries of these paths via RAMGEO. Analysis used only the direct, surface reflected, and bottom reflected signals on 8 array phones assuming a flat bottom for each path (Tolstoy, '05).

RESULTS

- Preliminary broadband FFT analysis and inversion via the SUB-RIGS method of the nw014 path of Haro St data show that the path *geometry* still needs to be determined prior to geoacoustic inversion. Ambiguities are overwhelming in the presence of undetermined geometry even at multiple frequencies.
- Time domain analyses of several paths of Haro St data (nw014, nw024, sw029) indicate that ambiguities are still a major concern requiring additional geometric analysis allowing for non-flat bottoms (sloping), additional surface and bottom reflections as possible, and more phones in the arrays. Progress for the early boundary reflections (a typical result is shown in Fig. 2) is very promising.

IMPACT/APPLICATION

This technique is likely to influence array technology, multiple array deployment, and the selection of propagation models used by the fleet for target detection, localization, and geoacoustic inversion. The estimation of true 3-D geoacoustic properties will be extremely important for the detection and localization of targets such as subs as well as of buried targets such as mines.

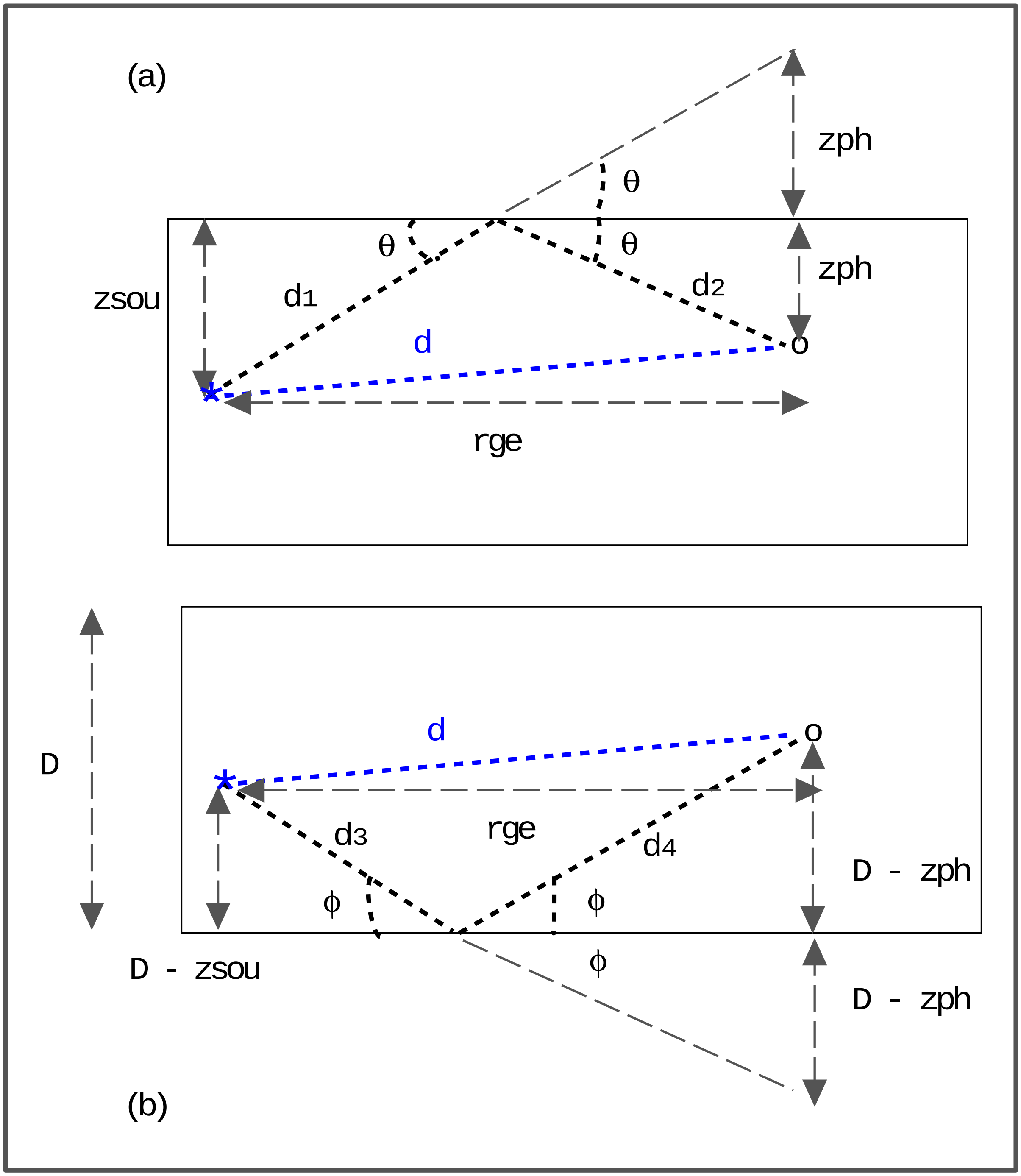

Figure 1: Geometric relationships between (a) the first surface reflected arrival distance ($d_1 + d_2$) and the direct arrival distance d; (b) the first bottom reflected arrival distance ($d_3 + d_4$) and the direct arrival distance d.

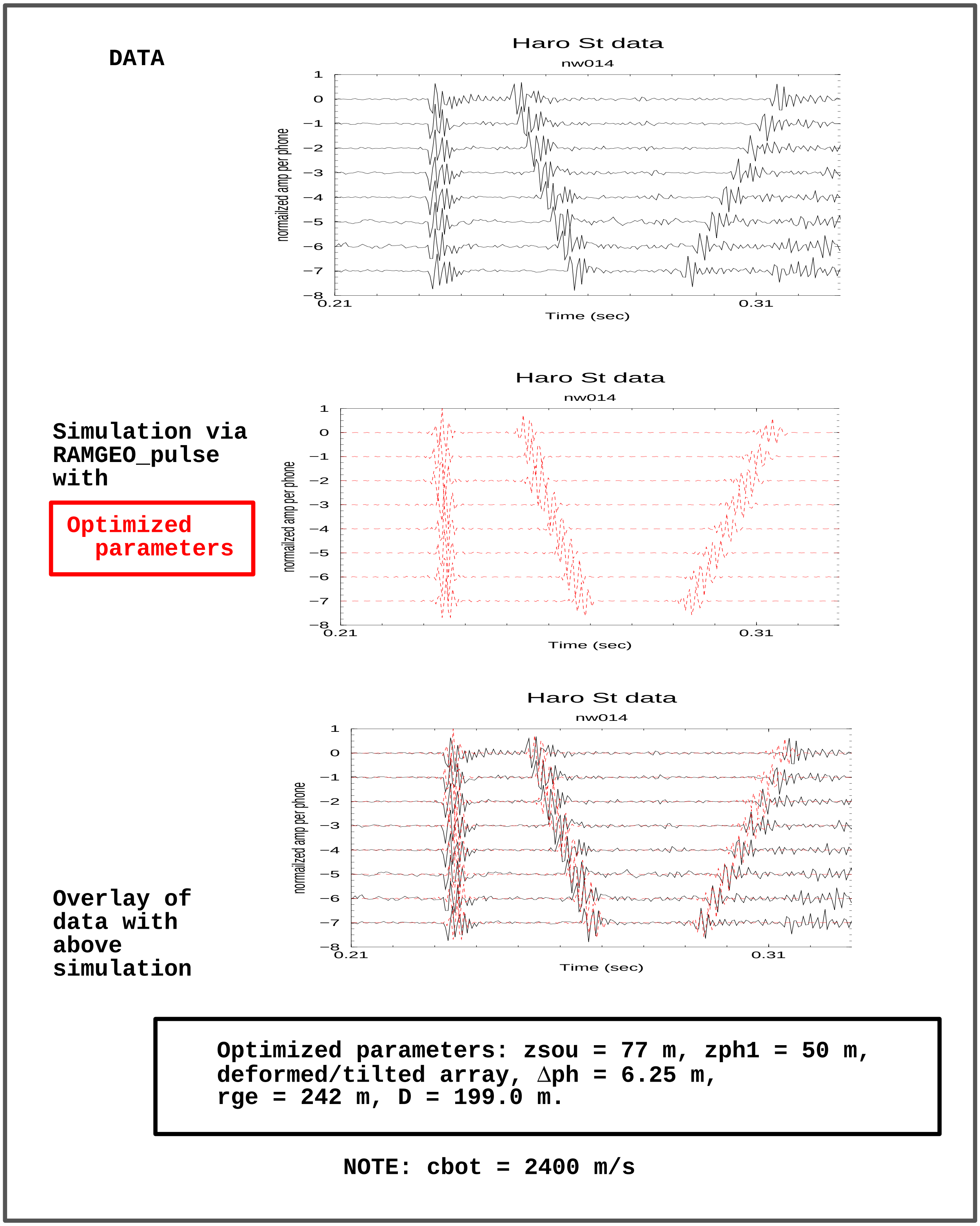

Figure 2: Data and simulated pulse fields at the NW array for the path from shot 14. (a) The data as a function of time and phone (array shown in Tolstoy, '05); (b) the field simulated via the pulse ramgeo for the optimal parameter values (Table 2 of Tolstoy, '05); (c) overlay of the data and simulated fields. The simulated data have been shifted to line up with the direct arrivals.

RELATED PROJECTS Investigations in the area of geoacoustic inversions are being conducted by the Canadians (N. Chapman et al. investigating the Haro Strait data; G. Heard et al.), Europeans (R. Hamson and M. Ainslie of Great Britain; S. Jesus of Portugal; D. Simons and M. Snellen of The Netherlands; Y. Stephan et al. of France; M. Taroudakis and M. Markaki of Greece; V. Westerlin of Sweden), and Asians (P. Ratilal et al. of Singapore; R. Zhang et al. of China). Moreover, geometric considerations are being examined by E. Michalopoulou at NJIT as well as by Skarsoulis et al. (Greece).

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PUBLICATIONS

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HONORS/AWARDS/PRIZES

- Co-editor for *International Conference on Theoretical and Computational Acoustics 2005*, World Scientific Publishers, in progress.
- Editor of JASA (since 7/03).
- Editorial Board of JCA.
- Invited talk "The Hunt for Red October and Underwater Acoustics" local ASA group, VA.
- ASA Committee Work: WIA (Mentoring contact), AO, UW, Springer Books.